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Numerical simulation of two-phase evaporation and condensation

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Numerical simulation of two-phase evaporation and condensation

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Abstract. The evaporation and condensation mechanism of two-phase flow is studied. The Euler-Euler pattern is used to express the evaporation and condensation properties of two-phase flow. The research shows that the tracking program can accurately track the interface. The thermal resistance on the confluence of the condensation part and insulation part becomes larger. The working fluids have significant influence of two-phase.

1. Introduction

The common classification method of multi-phase flow is based on the number of phases. The two-phase flow is the most studied by researchers, such as water and steam, acetone and acetone vapor. The phases flow can be sorted on the basis of working fluid properties. There are four main types: liquid-solid phases flow, which implies solid particles flow with the liquid; Gas-solid phases flow, which implies solid particles flow with gas; Liquid-liquid phases flow, which implies two kinds of liquids that cannot be uniformly mixed flow together; Gas-liquid phases flow, which implies gas and liquid flow together [1, 2]. In this article, gas-liquid of two-phase flow is studied.

Continuous medium patterns in two-phase flow include Euler-Lagrange pattern and Euler-Euler pattern. Euler-Lagrangian pattern is used for discrete patterns, one phase is discrete phase and the other phase is continuous phase. Euler-Euler pattern treats all phase as continuous media. The volume of fluid pattern, mixture pattern and euler pattern belong to Euler-Euler pattern. The volume of fluid pattern treats two-phase flow as single mixture. The two phase share the same velocity field and temperature field. It only needs to solve a set of mixed phase momentum equations and mixed phase energy equations.

This article can use the volume of fluid pattern. The volume of fluid pattern is applicable to stratified and free surface flow. The volume of fluid pattern pattern can use the geometric reconstruction pattern to track the gas-liquid interface, which has with the highest accuracy. Hirt and Nichols first used the volume of fluid method to simulate dam break, Rayleigh-Taylor instability and moving phase interface problems in 1981 [3].

2. Mathematical pattern

2.1. The Geometric pattern

In this article, the geometric pattern is shown in Figure 1. The pattern is separated into three parts: condensation part, insulation part and evaporation part from left to right [4].



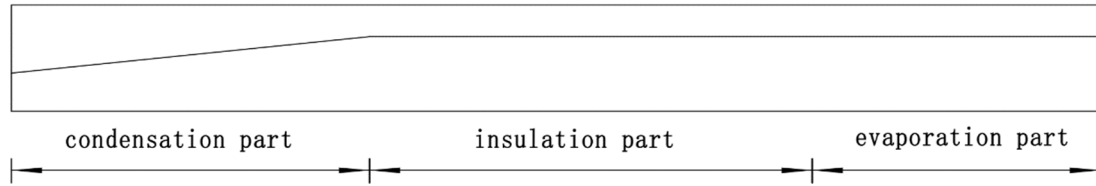


Figure 1. The geometric pattern.

2.2. The grid dividing

The Fluent software is used to divide grid. In this paper, the grid uses the quadrilateral structured. On the boundary between the fluid part and the solid part, the grid is concentrated on the fluid part to improve the calculating exactness, as shown in Figure 2.

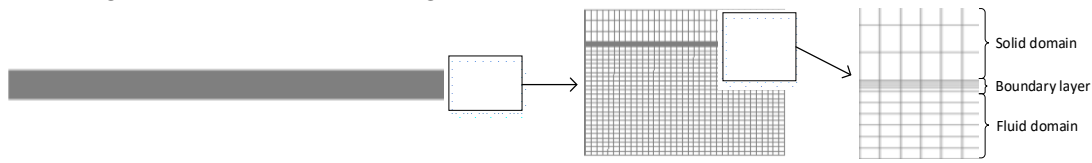


Figure 2. The grid dividing.

2.3. The equations of state

In gas-fluid flow, the confluence between phases is the continuous function by seeking the fraction in the gas phase [5]. The continuous functions are as follows in gas-fluid flow:

$$\frac{\partial \rho_1 \alpha_1}{\partial t} + \frac{\partial \rho_1 \alpha_1 u}{\partial x} + \frac{\partial \rho_1 \alpha_1 v}{\partial y} = S \quad (1)$$

$$\frac{\partial \rho_2 \alpha_2}{\partial t} + \frac{\partial \rho_2 \alpha_2 u}{\partial x} + \frac{\partial \rho_2 \alpha_2 v}{\partial y} = -S \quad (2)$$

There is mass exchange in gas-liquid flow. The gas-fluid flow can occur evaporation and condensation. When the whole parts solve the continuous functions, it only need to solve the fraction of the second phase. In this article, the first phase is gas. It not needs to calculate the continuous function of the gas. The continuous function of the second phase is calculated to gain the volume fraction of the second phase. It can need to calculate by equation (3) in the volume fraction of the second phase.

$$\alpha_1 + \alpha_2 = 1 \quad (3)$$

The momentum equation of gas-fluid in the whole parts is shared [6]. The velocity fields of gas-fluid need to be calculated. The velocity fields in the X and Y axes are built:

$$F_x \frac{\partial p}{\partial x} + \mu \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right) = \rho \left(\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} \right) \quad (4)$$

$$F_y \frac{\partial p}{\partial y} + \mu \left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} \right) = \rho \left(\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} \right) \quad (5)$$

The energy equation in the whole parts is one and the same. The temperature field is built:

$$\rho c \left(\frac{\partial T}{\partial t} + u \frac{\partial T}{\partial x} + v \frac{\partial T}{\partial y} \right) = \lambda \left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} \right) + S_e \quad (6)$$

In the equations, ρ_1 means density of the first phase. ρ_2 means density of the second phase. α_1 means volume fraction of the first phase. α_2 means volume fraction of the second phase. S means mass term. ρ means density of gas-fluid phase. c means specific heat of gas-fluid phase. S_e means energy term.

3. Numerical Simulation

In order to study the evaporator and condenser on the confluence of phases, it is necessary to find the gas-liquid confluence. Based on the found gas-liquid interface, the energy source term and mass source term are applied to the phase interface [7].

Although the cloud image function of FLUENT software can display the gas-liquid interface, the user cannot directly obtain the relevant information of the gas-liquid interface, and must write a program to track the phase interface to obtain the phase interface position and other information [8].

3.1. The gas-liquid interface

It can be seen from Figure 3 and Figure 4. This figures show the cloud image of gas-liquid on the evaporator part and condenser part. There is a layer of liquid film on the evaporator part and condenser part. The red line is the gas-liquid interface tracked by tracking program. It can be clearly seen that the program accurately tracks the gas-liquid interface. It lays a foundation for the mass term and energy term on the gas-liquid interface.



Figure 3. Interface on evaporation section.

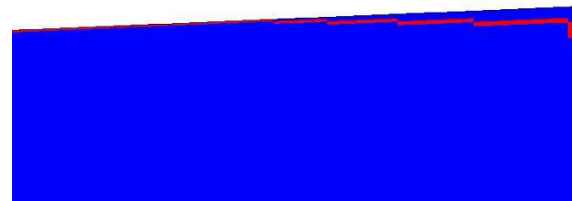


Figure 4. Interface on condensation section.

3.2. Temperature distribution on the wall

The fall of the temperature is produced on the confluence of the condensation part and insulation part, as shown in Figure 5. Due to a slope on condensation part, the water film gathers on the confluence of the condensation part and insulation part. The thickness of the second phase is much thicker on the condensation part. The thermal resistance becomes larger. Because it is the constant heat flow boundary condition, the temperature fall also becomes larger.

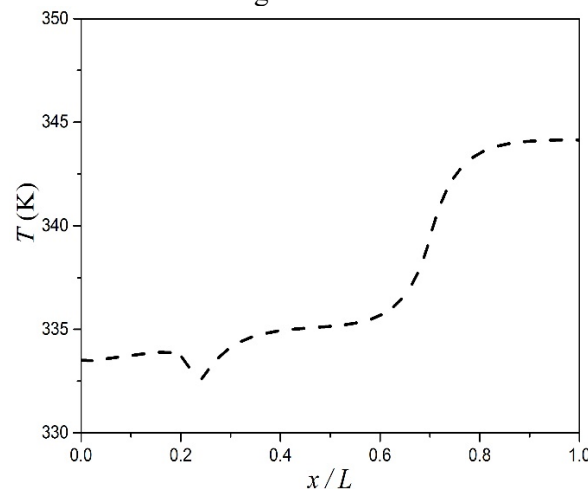


Figure 5. Temperature distribution on the wall.

3.3. Influence of different working fluids

In a similar case, the temperature fall by acetone are larger than water on the condensation part and evaporation part. It because that acetone has smaller thermal conductivity, as shown in Figure 6. The working fluids have significant influence of two-phase.

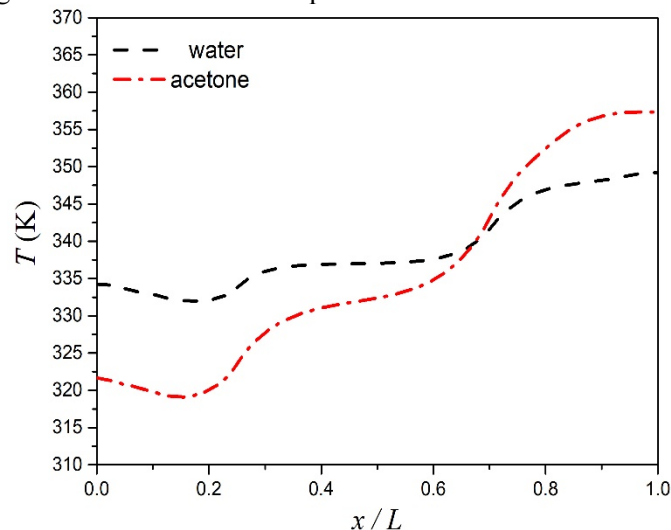


Figure 6. Temperature distribution of different working fluids.

4. Conclusion

A tracking program is used to track the phase interface to obtain the phase interface position and other information. The volume of fluid pattern is used in this article. The volume of fluid pattern is suitable for two-phase condensation and evaporation.

The research shows that the tracking program can accurately track the interface. The thermal resistance on the confluence of the condensation part and insulation part becomes larger. The working fluids have significant influence of two-phase. The results of numerical simulation can accurately describe two-phase condensation and evaporation. This paper lays the foundation for the study of two-phase condensation and evaporation, and it is expected to be applied to experimental research.

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